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Forliti et al.

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(54) **GYROSCOPE SHOCK AND DISTURBANCE DETECTION CIRCUIT**

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Related U.S. Application Data

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(60) Provisional application No. 61/816,419, filed on Apr. 26, 2013.

(51) **Int. Cl.**

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G01C 19/5726	(2012.01)
G01C 19/5719	(2012.01)
G01C 19/5776	(2012.01)
G01C 19/5733	(2012.01)

(52) **U.S. Cl.**

CPC ***G01C 19/5726*** (2013.01); ***G01C 19/5719*** (2013.01); ***G01C 19/5733*** (2013.01); ***G01C 19/5776*** (2013.01)

(58) **Field of Classification Search**

CPC G01C 19/5719; G01P 3/495; A63B 2220/40

USPC 73/504.02, 496, 503.3, 504.18, 514.13, 73/514.14, 739

See application file for complete search history.

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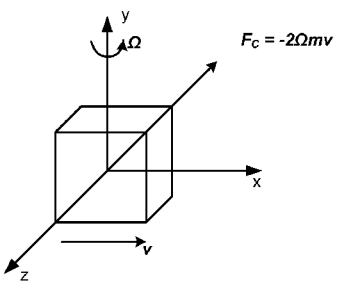
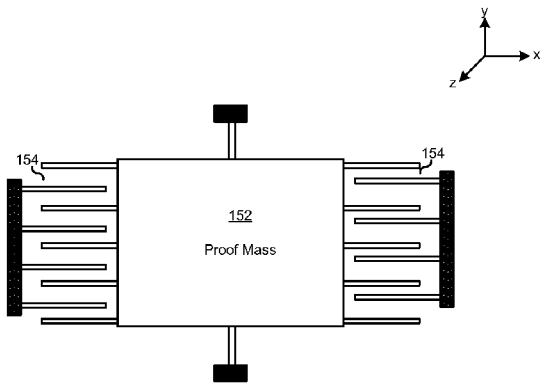
(57) **ABSTRACT**

The invention relates to integrated circuits, and more particularly, to systems, devices and methods of integrating a gyro sensing circuit with a gyroscope to detect a shock or a disturbance, and accurately differentiate rotation-based sense signals from noises introduced by the shock or disturbance. The gyro sensing circuit may be implemented in a differential or non-differential demodulation scheme, and comprises at least one demodulation unit and a peak detector. The at least one demodulation unit demodulates a gyro output signal provided by the gyroscope with a reference signal. In a demodulated gyro output signal, a shock signal or a gyro disturbance signal is substantially isolated out from interested gyro sense signals that are used to sense a rate of rotation. A peak detector samples the modulated gyro output signal, determines whether the signal exceeds a threshold level V_{TH} and outputs a shock flag indicating a corresponding determination result.

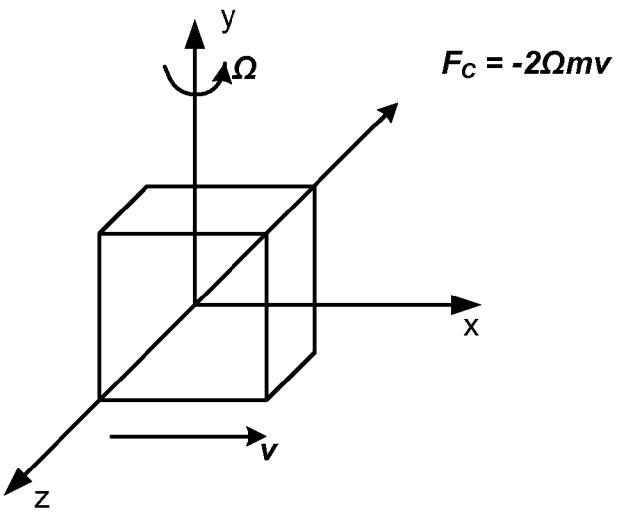
19 Claims, 9 Drawing Sheets



100

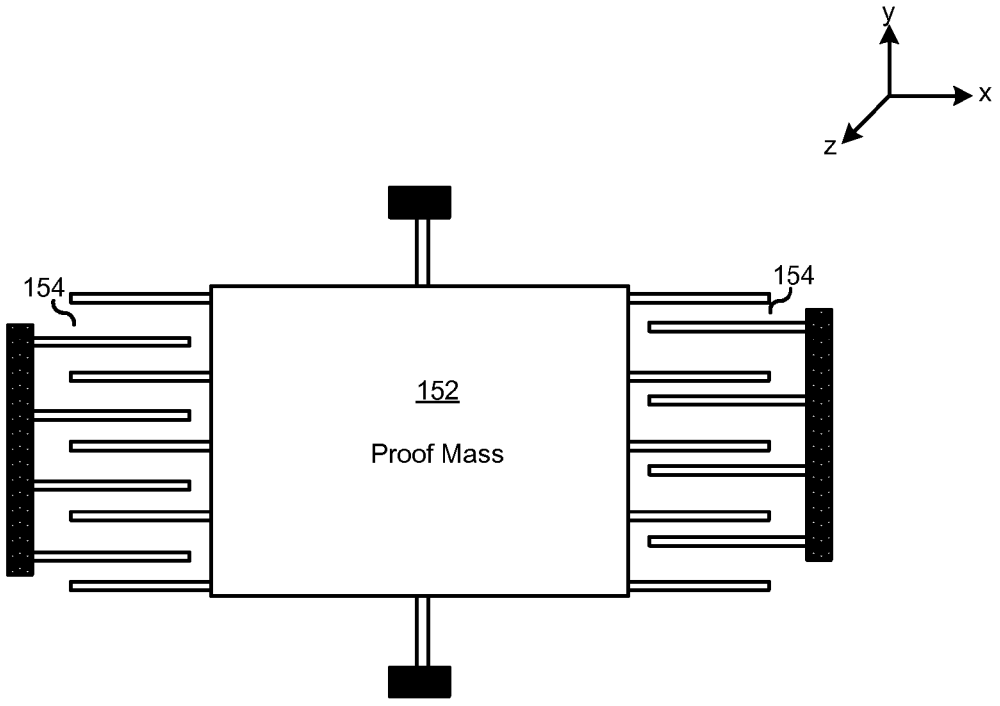


150



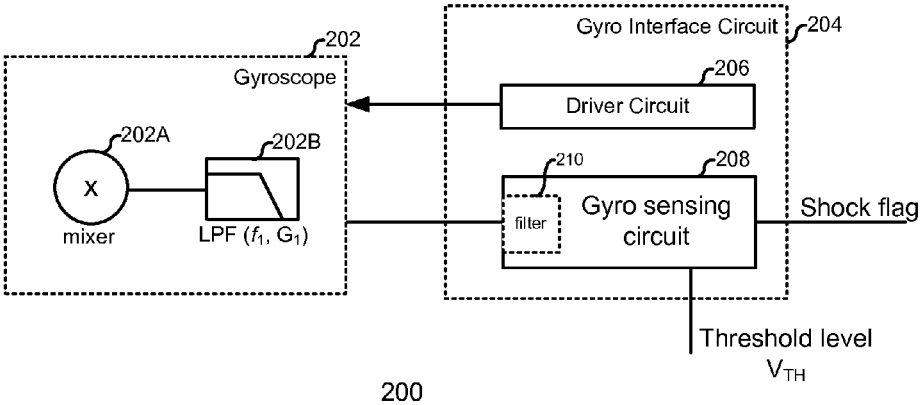
100

FIG. 1A



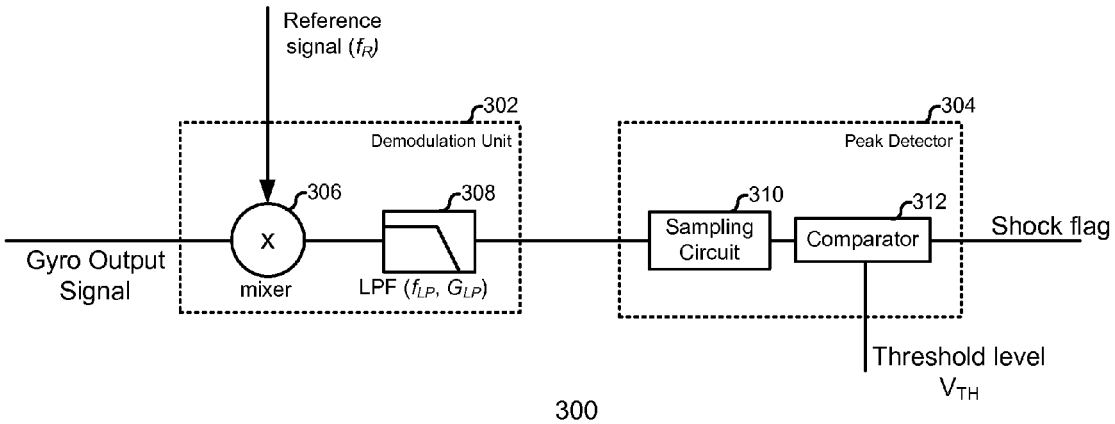
150

FIG. 1B



200

FIG. 2



300

FIG. 3

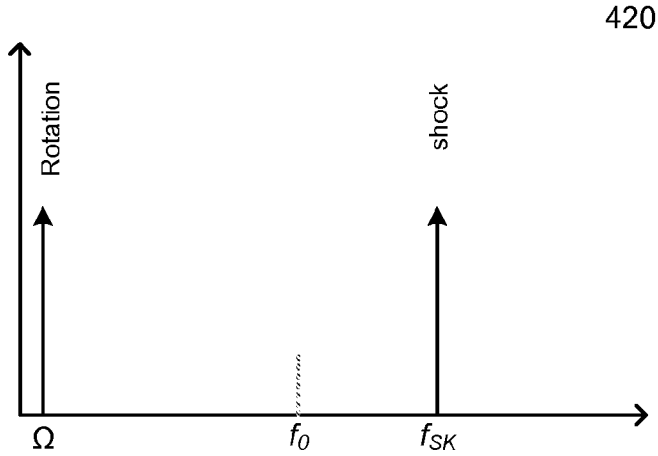


FIG. 4A

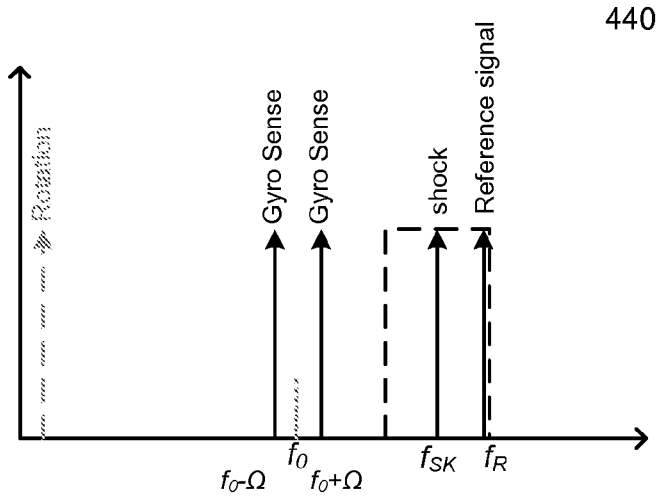


FIG. 4B

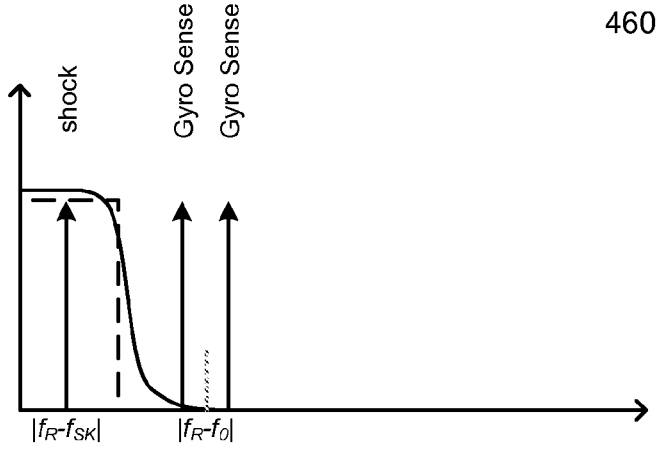


FIG. 4C

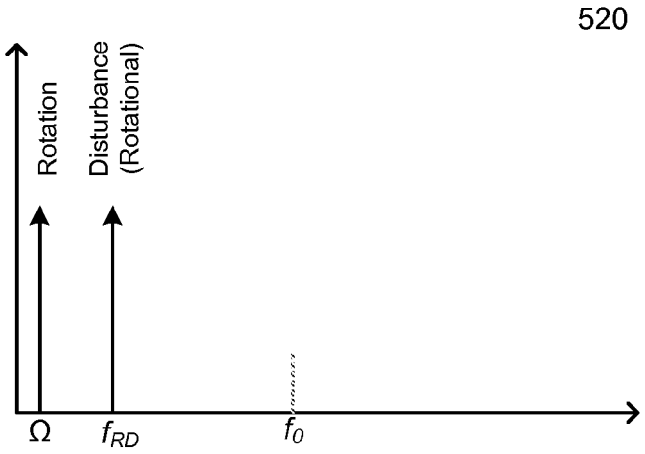


FIG. 5A

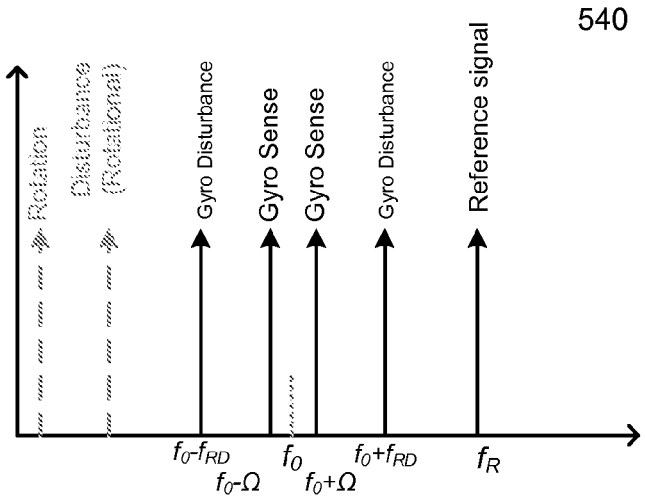


FIG. 5B

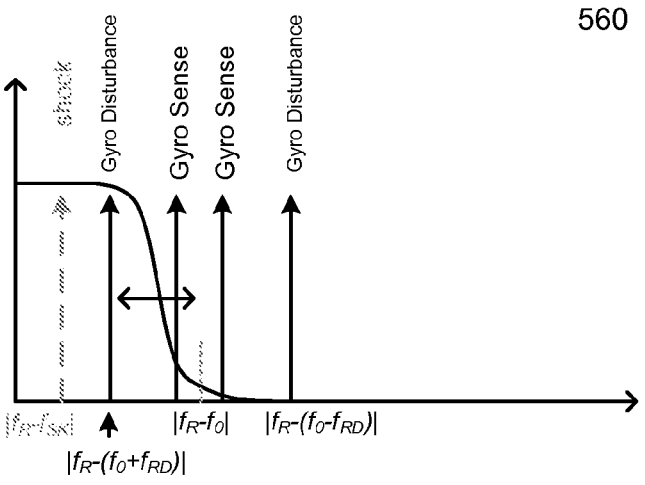
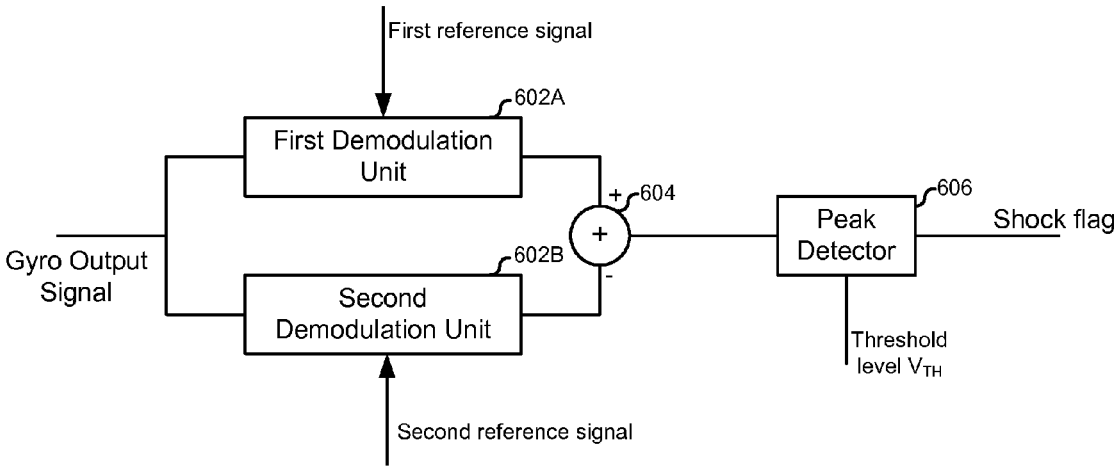


FIG. 5C


First reference signal
602A
First Demodulation Unit
+
604
606
Peak Detector
Shock flag
Gyro Output Signal
602B
Second Demodulation Unit
-
Threshold level V_{TH}
Second reference signal

600

FIG. 6

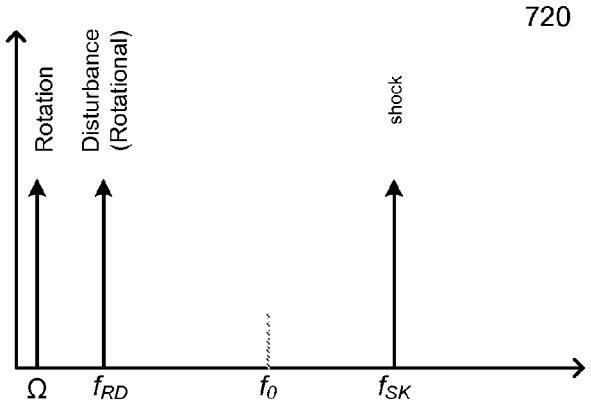


FIG. 7A

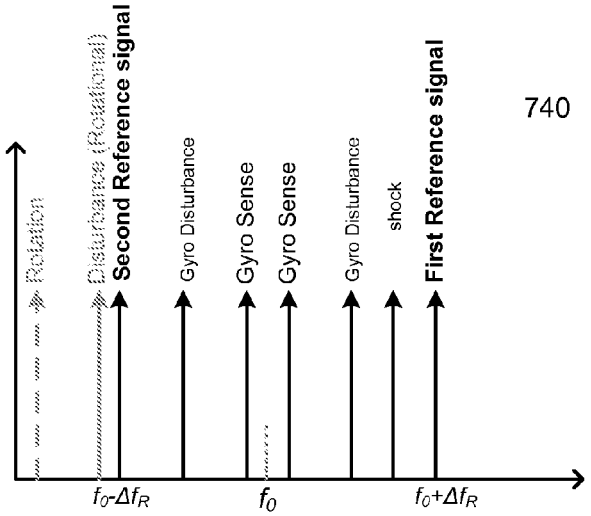


FIG. 7B

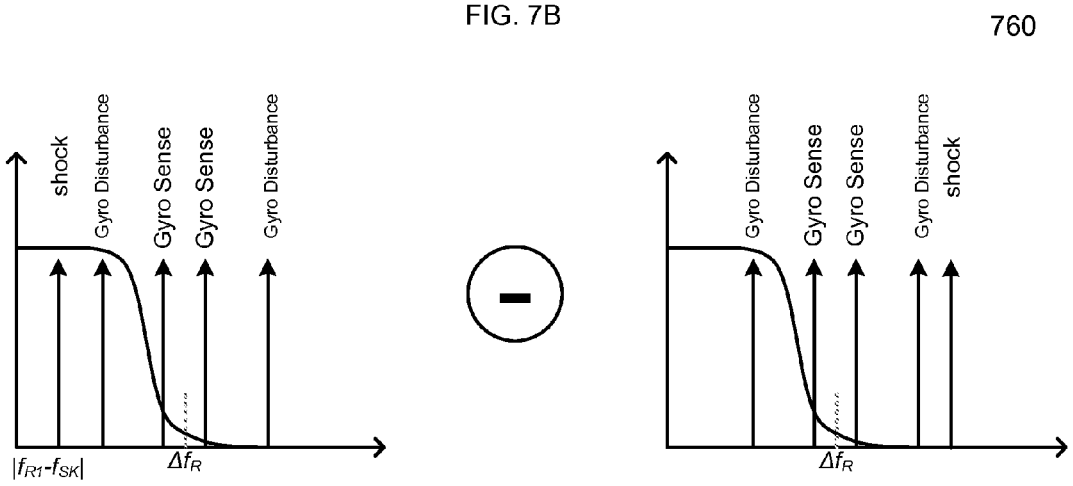
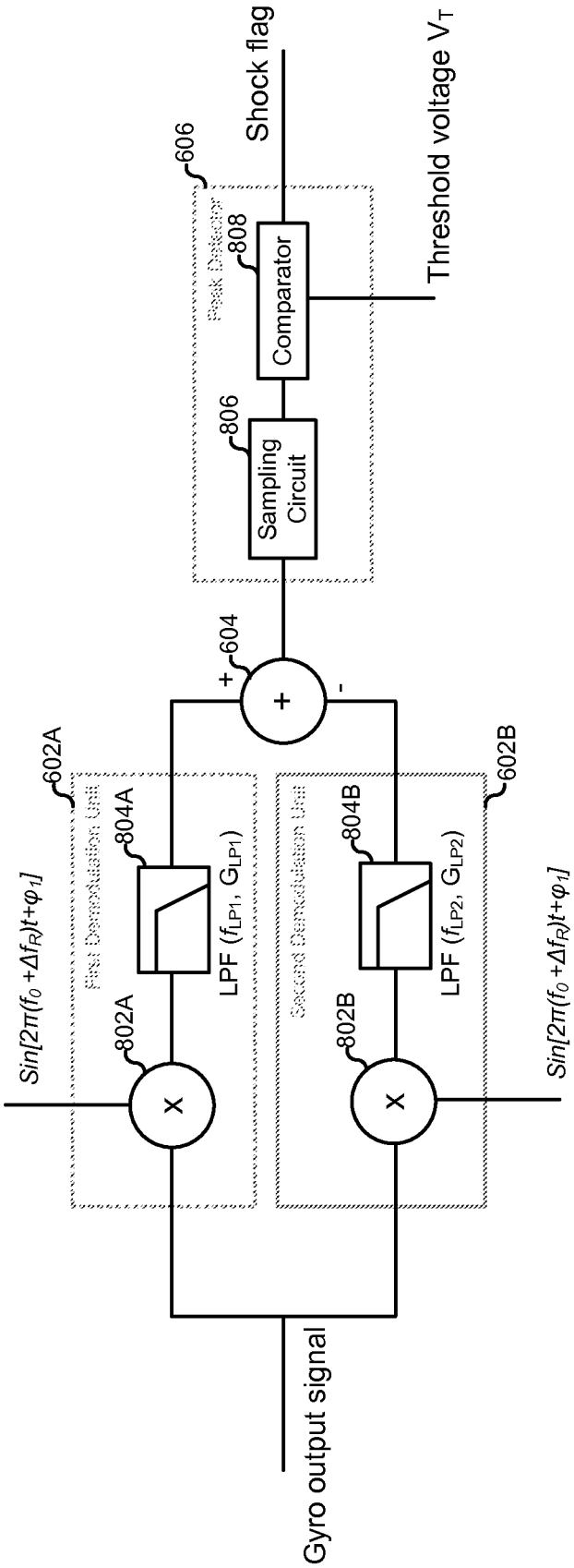
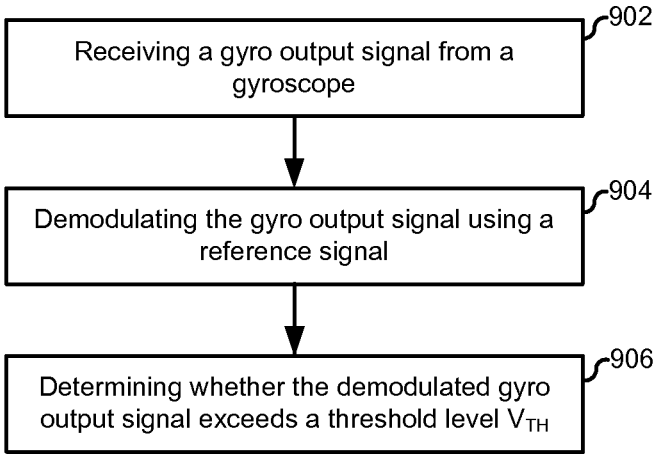


FIG. 7C


Shock flag
Threshold voltage V_T
606
Peak Detector
808
Comparator
806
Sampling Circuit
604
+
+
-
602A
First Demodulation Unit
804A
LPF (f_{LP1}, G_{LP1})
802A
$Sin[2\pi(f_0+\Delta f_R)t+\varphi_1]$
602B
Second Demodulation Unit
804B
LPF (f_{LP2}, G_{LP2})
802B
$Sin[2\pi(f_0+\Delta f_R)t+\varphi_1]$
Gyro output signal

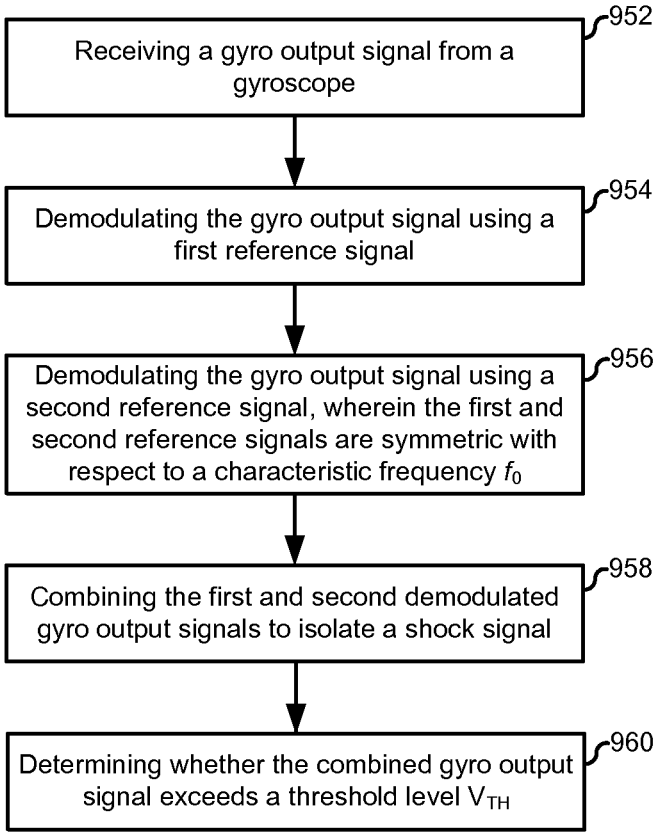
800

FIG. 8


Receiving a gyro output signal from a gyroscope
902
Demodulating the gyro output signal using a reference signal
904
Determining whether the demodulated gyro output signal exceeds a threshold level V_{TH}
906

900

FIG. 9A


Receiving a gyro output signal from a gyroscope
952
Demodulating the gyro output signal using a first reference signal
954
Demodulating the gyro output signal using a second reference signal, wherein the first and second reference signals are symmetric with respect to a characteristic frequency f_0
956
Combining the first and second demodulated gyro output signals to isolate a shock signal
958
Determining whether the combined gyro output signal exceeds a threshold level V_{TH}
960

950

FIG. 9B

GYROSCOPE SHOCK AND DISTURBANCE DETECTION CIRCUIT

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of previously filed and copending application Ser. No. 13/925,741, entitled, "Gyroscope Shock and Disturbance Detection Circuit, naming Massimiliano Forliti and Christian Rosadini as inventors, and filed Jun. 24, 2013, which application claims the benefit under 35 U.S.C. §119(e) of Provisional Application No. 61/816,419, entitled "Gyroscope Shock and Disturbance Detection Circuit," filed Apr. 26, 2013, which applications are hereby incorporated herein by reference in their entireties.

BACKGROUND

A. Technical Field

The present invention relates to integrated circuits, and more particularly, to systems, devices and methods of detecting a shock or a disturbance experienced by a gyroscope and differentiating rotation-based sense signals from noises introduced by the shock or disturbance.

B. Background of the Invention

A microelectromechanical structure (MEMS) is widely applied as a sensor to measure acceleration, rotation, pressure and many other physical parameters. The MEMS device is normally formed on a silicon substrate using a micromachining process, adopts characteristic feature sizes of several micrometers, and transduces mechanical movement to electrical signals that may indicate the level of an interested parameter. In particular, MEMS-based gyroscope devices have been developed and applied to monitor rotational rates of the devices with respect to certain axes, and a multitude of consumer and automotive applications have successfully adopted such MEMS-based gyroscope devices. For instance, many automotive integrate the gyroscope devices for vehicle stability control, navigation assist, load leveling/suspension control, collision avoidance and roll over detection.

Conventional MEMS-based gyroscope devices use vibrational mechanical elements (proof masses) to sense a rate of rotation. FIG. **1**A illustrates a mechanical element **100** disposed in a rotating reference frame. The mechanical element **100** is driven to oscillate in a first orthogonal axis (x-axis), and as the frame rotates with respect to a second orthogonal axis (y-axis), vibratory movement is induced along the third orthogonal axis (z-axis) due to Coriolis acceleration. A corresponding inertial Coriolis force F_C may be represented as:

$$F_C = -2\Omega m v \quad (1)$$

where Ω is the rate of rotation, m is the mass of the mechanical element **100** and v is the vibrational velocity along the first orthogonal axis.

FIG. **1**B illustrates an exemplary vibratory gyroscope device **150** that relies on electrostatic actuation and capacitive sensing to detect the Coriolis force. A proof mass **152** is driven to vibrate along an x-axis by comb drivers **154** arranged at two opposing sides. A capacitor is formed between the substrate and the proof mass **152**. In response to rotation with respect to a y-axis, the proof mass **152** vibrates towards and away from a substrate that the gyroscope device **150** is situated on, and therefore, the gap distance of the capacitor varies, leading to a capacitive variation that is associated with the Coriolis force. An interface readout circuit is normally integrated with the gyroscope device **150** to convert this capacitive variation to a gyroscope sense signal that is related to the magnitude of the Coriolis force and therefore to the corresponding rate of rotation.

Although the gyroscope sense signal includes interested information related to the rate of rotation, noises are also introduced by various shock and disturbance sources and could significantly compromise the accuracy of rotation sensing. Particularly in automotive applications, shock robustness is critical and constitutes a key characteristic, because strict safety constraints have to be imposed to ensure a failsafe and robust system. In such a context, an occurrence of shock or disturbance needs to be flagged and used to indicate that an unreliable and unpredictable rate signal is outputted, when the level of the shock or disturbance exceeds a threshold value tolerable by a corresponding rotation sensing system. Many existing gyroscope devices in the market have adopted sensor or package solutions to improve shock robustness of the devices themselves. However, none of them flags the occurrence of shock or disturbance with respect to a certain tolerance, and warns a host to take suitable countermeasures.

SUMMARY OF THE INVENTION

Various embodiments of the invention relate to integrated circuits, and more particularly, to systems, devices and methods of integrating a gyro sensing circuit with a gyroscope to detect a shock or a disturbance experienced by a gyroscope device and accurately differentiate rotation-based gyro sense signals from noises introduced by the shock or disturbance. The gyro sensing circuit specifically takes advantages of the symmetry of these signals with respect to a characteristic frequency of the gyroscope.

In accordance with one embodiment of the invention, a gyro sensing circuit is implemented based on a differential demodulation scheme. Two demodulate units are applied to demodulate a gyro output signal that comprises a shock signal and a plurality of gyro sense signals. Two reference signals that are symmetric with respect to the characteristic frequency are used for the demodulation, and the resulting demodulated gyro outputs are differentially combined in a subtractor to isolate the shock signal that is asymmetric with respect to the characteristic frequency. A peak detector further determines whether the combined gyro output exceeds a threshold level, and generates a shock flag to alert a host whether an anomalous shock or disturbance situation occurs.

In accordance with another embodiment of the invention, a gyro sensing circuit is implemented based on a non-differential demodulation scheme. The gyro sensing circuit comprises a demodulation unit and a peak detector. The demodulation unit is first coupled to receive a gyro output signal that comprises a gyro sense signal and at least one of a shock signal and a plurality of gyro disturbance signals from a gyroscope. Such a gyro output signal is demodulated using a reference signal, such that the at least one of the shock signal and the plurality of gyro disturbance signals is retained while the gyro sense signal that is related to an interested rate of rotation is suppressed. The peak detector determines whether the demodulated gyro output exceeds a threshold level and generates a shock flag to alert a host whether an anomalous shock or disturbance situation occurs.

Certain features and advantages of the present invention have been generally described here; however, additional

features, advantages, and embodiments are presented herein will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims hereof. Accordingly, it should be understood that the scope of the invention is not limited by the particular embodiments disclosed in this summary section.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference will be made to embodiments of the invention, examples of which may be illustrated in the accompanying figures. These figures are intended to be illustrative, not limiting. Although the invention is generally described in the context of these embodiments, it should be understood that it is not intended to limit the scope of the invention to these particular embodiments.

FIG. **1**A illustrates a mechanical element disposed in a rotating reference frame.

FIG. **1**B illustrates an exemplary vibratory gyroscope device that relies on electrostatic actuation and capacitive sensing to detect a Coriolis force.

FIG. **2** illustrates an exemplary rotation sensing system according to various embodiments in the invention.

FIG. **3** illustrates an exemplary block diagram of a gyro sensing circuit based on a non-differential demodulation scheme according to various embodiments in the invention.

FIG. **4**A illustrates a first exemplary spectrum diagram of inputs coupled into a rotation sensing system according to various embodiments in the invention.

FIG. **4**B illustrates a first exemplary spectrum diagram of signal components in a gyro output signal and a reference signal used in a gyro sensing circuit according to various embodiments in the invention.

FIG. **4**C illustrates an exemplary spectrum diagram that indicates a mechanism to separate a shock signal from two gyro sense signals in a gyro output signal according to various embodiments in the invention.

FIG. **5**A illustrates a second exemplary spectrum diagram of inputs coupled into a rotation sensing system according to various embodiments in the invention.

FIG. **5**B illustrates a second exemplary spectrum diagram of signal components in a gyro output signal and a reference signal used in a gyro sensing circuit according to various embodiments in the invention.

FIG. **5**C illustrates an exemplary spectrum diagram that indicates a mechanism to separate one of two gyro disturbance signals from the two gyro sense signals in a gyro output signal according to various embodiments in the invention.

FIG. **6** illustrates an exemplary block diagram of a gyro sensing circuit based on a differential demodulation scheme according to various embodiments in the invention.

FIG. **7**A illustrates a third exemplary spectrum diagram of inputs coupled into a rotation sensing system according to various embodiments in the invention.

FIG. **7**B illustrates an exemplary spectrum diagram of signal components in a gyro output signal and two reference signals used in a gyro sensing circuit according to various embodiments in the invention.

FIG. **7**C illustrates an exemplary spectrum diagram that indicates a differential demodulation mechanism to separate a shock signal from gyro sense and disturbance signals a gyro output signal according to various embodiments in the invention.

FIG. **8** illustrates another exemplary block diagram of a gyro sensing circuit based on a differential demodulation scheme according to various embodiments in the invention.

FIG. **9**A illustrates an exemplary flow diagram of a method for flagging a disturbance or a shock experienced by a rotation sensing system according to various embodiments in the invention.

FIG. **9**B illustrates another exemplary flow diagram of a method for flagging a shock experienced by a rotation sensing system according to various embodiments in the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following description, for the purpose of explanation, specific details are set forth in order to provide an understanding of the invention. It will be apparent, however, to one skilled in the art that the invention can be practiced without these details. One skilled in the art will recognize that embodiments of the present invention, described below, may be performed in a variety of ways and using a variety of means. Those skilled in the art will also recognize additional modifications, applications, and embodiments are within the scope thereof, as are additional fields in which the invention may provide utility. Accordingly, the embodiments described below are illustrative of specific embodiments of the invention and are meant to avoid obscuring the invention.

Reference in the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, characteristic, or function described in connection with the embodiment is included in at least one embodiment of the invention. The appearance of the phrase "in one embodiment," "in an embodiment," or the like in various places in the specification are not necessarily all referring to the same embodiment.

Furthermore, connections between components or between method steps in the figures are not restricted to connections that are effected directly. Instead, connections illustrated in the figures between components or method steps may be modified or otherwise changed through the addition thereto of intermediary components or method steps, without departing from the teachings of the present invention.

Various embodiments of the invention relate to integrated circuits, and more particularly, to systems, devices and methods of integrating a gyro sensing circuit with a gyroscope to detect a shock or a disturbance experienced by a gyroscope device and accurately differentiate rotation-based gyro sense signals from noises introduced by the shock or disturbance. In addition to the rotation-based gyro sense signals, gyro disturbance signals or a shock signal may be incorporated in a gyro output signal provided by the gyroscope device to the gyro sensing circuit, but these signals have different frequency magnitudes and characteristics. When the shock signal exceeds a threshold level, the gyro output signal is corrupted, and a rate of rotation derived from the gyro output signal is not reliable any more. Sometimes, the gyro output signal is also regarded as corrupted when one of the gyro disturbance signals exceeds the threshold level.

In accordance with the invention, the gyro sensing circuit is configured according to a differential or non-differential demodulation scheme, and applies at least one reference signal to demodulate the gyro output signal. The reference frequency of the at least one reference signal is selected according to the frequencies of the shock signal or the gyro disturbance signals, such that the shock or disturbance signals may be separated from the rotation-based gyro sense

signals in the gyro output signal. The shock or disturbance signals are constantly monitored, and any anomalous situation is flagged out to a host that relies on the gyroscope for rotation sensing. Upon detection of such conditions, the host may take suitable countermeasures, such as ignoring the corrupted gyro output signal, to ensure the accuracy of rotation sensing.

FIG. **2** illustrates an exemplary rotation sensing system **200** according to various embodiments in the invention. The rotation sensing system **200** comprises a gyroscope device **202** and a gyro interface circuit **204** that further comprises a driver circuit **206** and a gyro sensing circuit **208**. In accordance with various embodiments of the invention, the gyroscope device **202** is a MEMS device manufactured from a micro-fabrication process. The driver circuit **206** provides a drive signal to electrostatically drive a proof mass included in the gyroscope device **202**, and the proof mass is therefore driven to oscillate along a first orthogonal direction in a rotating reference frame. The drive signal preferably has a drive frequency that is consistent with a characteristic frequency f_0 of the gyroscope device **202**. In response to rotation with respect to a second orthogonal direction, the proof mass oversees a physical displacement along a third orthogonal direction and a corresponding capacitive variation. The gyro sensing circuit **208** is coupled to sense the capacitive variation which is associated with a corresponding Coriolis force along the third orthogonal direction.

The gyroscope **202** provides a gyro output signal to the gyro sensing circuit **204**, and this gyro output signal contains gyro sense signals resulting from an interested rotation rate of the gyroscope **202**. In a preferred embodiment, the gyro output signal is only associated with the capacitive variation caused by the Coriolis force, and contains only the gyro sense signals. However, in many cases, a shock or disturbance may be incorporated and unavoidably impact the gyro output signal. Therefore, the gyro output signal oftentimes includes a shock signal or gyro disturbance signals induced by the shock or disturbance, respectively.

In accordance with the present invention, the gyro sensing circuit **208** detects and flags an undesirable shock or disturbance in addition to rotation sensing, when a certain shock or disturbance signal contained in the gyro output signal exceeds a threshold level. Under such circumstances, useful information concerning a rate of rotation associated with the gyro output signal is corrupted by the excessive shock or disturbance signal and rendered inaccurate. Accordingly, an application host that adopts the rotation sensing system **200** may rely on a shock flag generated by the gyro sensing circuit **208** to determine whether the gyro output signal needs to be ignored and dissociated from the interested rate of rotation.

The mechanical structure of the gyroscope device **202** may be abstractly represented in theory as a combination of a mixer **202**A and a low-pass filter **202**B. The mixer **202**A mixes the drive signal and the rate of rotation, and generates an intermediate gyro output signal that is associated with the corresponding Coriolis force. The intermediate gyro output signal is further filtered to generate the gyro output signal. The low-pass filter **202**B is associated with a transfer function $H_p(s)$ that has a resonance peak at a peak frequency f_1. The cut-off frequency of the low-pass filter **202**B is substantially consistent with the peak frequency f_1. The characteristic frequency f_0 of the gyroscope device **202** is smaller than the peak frequency f_1, and thus, the gyro output signal may accurately maintain the interested information related to the rate of rotation. In one specific embodiment, the characteristic frequency f_0 and the peak frequency f_1 are respectively 20 kHz and 21 kHz.

An analog filter **210** may be further disposed at an input of the gyro sensing circuit **208**. The analog filter **210** is a low-pass filter used to filter, scale or amplify the gyro output signal prior to any further processing. The analog filter **210** serves anti-aliasing purposes, and does not affect the rotation-related spectrum content of the gyro output signal. Therefore, the cut-off frequency of the analog filter **210** is selected to be larger than both the characteristic frequency f_0 and the peak frequency f_1. For example, the cut-off frequency of the analog filter **210** may be set as 100 kHz, when the characteristic frequency f_0 and the peak frequency f_1 of the gyroscope **202** are respectively 20 kHz and 21 kHz.

In some embodiments, the gyro output signal provided by the gyroscope **202** is an analog signal. Upon filtering and scaling/amplification within the analog filter **210**, the gyro output signal is converted to a digital signal that may be further processed in a digital domain to obtain the rate of rotation and generate the flag output.

In certain embodiments, the gyroscope device **202** and the gyro interface circuit **204** are manufactured on two separate substrates, and assembled to form the rotation sensing system **200** in a hybrid format. In some other embodiments, the gyroscope device **202** and the gyro interface circuit **204** are manufactured on one single substrate using a micro-fabrication process that involves multiple layers of material. Even though they may occupy distinct chip estates that are physically separated on the substrate, the gyroscope device **202** may also be integrated on top of the gyro interface circuit **204** to save the chip estate. For such a vertical integration, the manufacturing process, the material layers and the configurations of both the gyroscope device **202** and the interface circuit **204** have to be properly arranged.

FIG. **3** illustrates an exemplary block diagram **300** of a gyro sensing circuit based on a non-differential demodulation scheme according to various embodiments in the invention. The gyro sensing circuit **300** generates a shock flag that indicates whether a shock or disturbance signal exceeds a threshold level V_{TH}, and therefore, the application host may rely on the shock flag to determine whether the gyro output signal is corrupted and needs to be ignored.

The gyro sensing circuit **300** comprises a demodulation unit **302** and a peak detector **304**. The demodulation unit **302** demodulates a gyro output signal using a reference signal, such that the shock or disturbance signal is retained while the gyro sense signals are suppressed within a demodulated gyro output signal. By this means, the shock or disturbance signal is effectively separated out from the gyro sense signals. The peak detector **304** further detects whether the magnitude of the demodulated gyro output signal exceeds a threshold level V_{TH}, and generates the corresponding shock flag to alert the host whether an anomalous shock or disturbance situation occurs.

The demodulation unit **302** further comprises an electronic mixer **306** and a low-pass filter **308**. The electronic mixer **306** combines the reference signal and the gyro output signal, and varies the spectrum contents of the gyro output signal with respect to a reference frequency f_R of the reference signal. The low-pass filter **308** adopts a gain G_{LP} and a cut-off frequency f_{LP} that are designed to differently process the shock or disturbance signal and the gyro sense signals in the gyro output signal, and in particular, to retain or amplify the level of the shock or disturbance signal while suppressing that of the gyro sense signals. A selection method is applied to determine the reference frequency f_R, the cut-off frequency f_{LP} and the gain G_{LP}, and a corre-

sponding rationale underneath such a selection method is detailed below in FIGS. **4**A-**4**C and FIGS. **5**A-**5**C.

The peak detector **304** comprises a sampling circuit **310** and a comparator **312**. The sampling circuit **310** samples the demodulated gyro output signal received from the demodulation unit **302**. The comparator **312** compares the sampled signal with the threshold level V_{TH} and generates the shock flag according to a comparison result.

FIG. **4**A illustrates a first exemplary spectrum diagram **420** of inputs coupled into a rotation sensing system according to various embodiments in the invention. Rotation of the gyroscope device **202** is incorporated via the capacitive variation associated with the Coriolis force, and normally has a relatively low rotation frequency Ω. Such a rotation is directly associated with vehicle motion, when the host is a vehicle, and represents a useful signal that a supplier or a user of a host is interested in. The rate of rotation is normally located at a lower end of the frequency spectrum. In some embodiments, the rotation frequency Ω may be limited below 300 Hz.

A mechanical shock is normally introduced to the rotation sensing system **200** by acceleration stimuli or generic vibrations that are experienced by the host. The shock is directly incorporated into the gyro output signal without mechanical modulation by the gyroscope device **202**. Therefore, a shock frequency f_{SK} associated with the shock is not limited by the low-pass filter **202**B, and in certain embodiments, may be higher than the characteristic frequency f_0 or the peak frequency f_1 of the gyroscope **202**. In one embodiment, the shock frequency f_{SK} approximately extends up to 30 kHz, when the characteristic frequency f_0 and the peak frequency f_1 of the gyroscope **202** are respectively 20 kHz and 21 kHz.

FIG. **4**B illustrates a first exemplary spectrum diagram **440** of signal components in a gyro output signal and a reference signal used in a gyro sensing circuit according to various embodiments in the invention. Based on equation (1), the rotation of the gyroscope **202** is modulated to two gyro sense signals that are symmetric around the characteristic frequency f_0. Two sense frequencies of these two gyro sense signals are respectively $f_0-\Omega$ and $f_0+\Omega$, and in certain embodiments, the sense frequencies may range from DC to 15 kHz. On the other hand, the shock signal is not modulated by the gyroscope **202**, and directly incorporated into the gyro output signal. The first gyro sense signal, the second gyro sense signal and the shock signal constitute the signal components of the gyro output signal received from the gyroscope **202**.

In view of the signal components, the reference frequency f_R of the reference signal is particularly selected to be closer to the shock frequency f_{SK} than to either of the two gyro sense frequencies $f_0-\Omega$ and $f_0+\Omega$. On one hand, the reference frequency f_R also needs to be sufficiently far from the peak frequency f_1 of the gyroscope **202**. This is particularly due to the fact the peak frequency f_1 is associated with an intrinsic vibrational mode of the gyroscope **202** and that a spurious amplified response may be undesirably produced around this peak frequency f_1. On the other hand, the reference frequency f_R is not so far from the shock frequency that a response from the shock signal could be compromised as well

In certain embodiments, the shock signal is not limited to one single frequency, and the shock frequency f_{SK} is associated with a bandwidth BW_{SK}. The reference frequency f_R is still similarly determined as above, but particularly selected to be close to or within the frequency span of the shock frequency f_{SK}.

FIG. **4**C illustrates an exemplary spectrum diagram **460** that indicates a mechanism to separate the shock signal from the two gyro sense signals according to various embodiments in the invention. The shock signal and the two gyro sense signals are converted with respect to the reference signal, and change to different frequencies from their original frequencies in the electronic mixer **306**. The characteristic frequency f_0 is converted to a demodulated characteristic frequency $|f_R-f_0|$. Likewise, the modulated frequencies of the shock signal and the two gyro sense signals are $|f_R-f_{SK}|$, $|f_R-(f_0-\Omega)|$ and $|f_R-(f_0+\Omega)|$, respectively. The absolute values are applied, because in some embodiments, the reference frequency f_R is smaller than the shock frequency f_{SK} or the gyro sense frequency $f_0-\Omega$.

In this embodiment, the reference frequency f_R is larger than both the shock frequency f_{SK} and the gyro sense frequencies $f_0-\Omega$ and $f_0+\Omega$. The modulated frequencies of the shock signal and the two gyro sense signals may be simply represented as f_R-f_{SK}, $f_R-(f_0-\Omega)$ and $f_R-(f_0+\Omega)$, respectively

The cut-off frequency f_{LP} of the low-pass filter **308** is controlled between the modulated shock frequency $|f_R-f_{SK}|$ and the modulated gyro sense frequencies, i.e., $|f_R-(f_0-\Omega)|$ and $|f_R-(f_0+\Omega)|$. The level of the shock signal is retained or amplified by the gain G_{LP}. On the opposite, the first and second gyro sense signals are depressed. Upon such modulations based on mixing and low pass filtering, the shock signal in the gyro output signal is separated, and the peak detector **304** may further determine whether the shock signal exceeds the threshold level V_{TH}.

One of those skilled in the art knows that the gyro sensing circuit **300** is preferably applied when the shock signal is not modulated by the gyroscope device **202** and relatively distant from the gyro sense signals on the frequency spectrum. The difference between the shock frequency f_{SK} and the sense frequencies $f_0\pm\Omega$ needs to be sufficiently large, such that the cut-off frequency f_{LP} may be controlled to a magnitude in between of them.

The modulation method based on one demodulation unit **302** is not applicable when the shock frequency f_{SK} is substantially close to either of the sense frequencies $f_0-\Omega$ and $f_0+\Omega$ in FIG. **4**C. Substantial closeness of the shock frequency with another frequency is determined based on whether the cut-off frequency f_{LP} of the low-pass filter **308** may be engineered to differentiate the corresponding modulated frequencies. To be specific, in one embodiment associated with FIG. **4**C, a challenge occurs for the gyro sensing circuit **300** that is based on a single modulation unit **302**, when the modulated shock frequency f_R-f_{SK} and the modulated gyro sense frequency $f_R-f_0-\Omega$ is so close that the low-pass filter **308** may not be easily engineered to differentiate them.

However, in some embodiments, the gyroscope **202** may further couple rotational disturbance besides the interested rotation of the host. When the host is a vehicle, such rotational disturbance may result from internal vehicle vibration or parasitic vibration of a gyroscope package. In particular, the rotational disturbance is modulated by the gyroscope **202** to generate gyro disturbance signals that have symmetric disturbance frequencies with respect to the characteristic frequency f_0.

FIG. **5**A illustrates a second exemplary spectrum diagram **520** of inputs coupled into a rotation sensing system according to various embodiments in the invention. In addition to interested rotation, a rotational disturbance to the gyroscope device **202** is also incorporated via the capacitive variation associated with the Coriolis force. Such a rotational distur-

bance has a disturbance frequency f_{RD} that is normally located within an intermediate frequency range, e.g., 1-5 kHz. In many embodiments, the disturbance frequency f_{RD} is smaller than the characteristic frequency f_0 of the gyroscope **202**.

FIG. **5**B illustrates a second exemplary spectrum diagram **540** of signal components in a gyro output signal and a reference signal used in a gyro sensing circuit according to various embodiments in the invention. Similarly, the rotational disturbance of the gyroscope **202** is modulated to two gyro disturbance signals that are symmetric with respect to the characteristic frequency f_0. Two gyro disturbance frequencies of these two gyro disturbance signals are respectively f_0-f_{DR} and f_0+f_{DR}. These two gyro disturbance signals and the two gyro sense signals constitute the signal components in the gyro output signal received from the gyroscope **202**. The gyro disturbance signals are further apart from the characteristic frequency f_0 compared with the gyro sense signals, because the rotational disturbance normally has a higher frequency than that of the interested rotation itself.

In view of these signal components, the reference frequency f_R of the reference signal is particularly selected to be closer to either of the two gyro disturbance frequencies f_0-f_{DR} and f_0+f_{DR} than to both gyro sense frequencies $f_0-\Omega$ and $f_0+\Omega$. To be specific, the reference frequency f_R may be selected to be smaller than the characteristic frequency f_0, and therefore, closer to the gyro disturbance frequency f_0-f_{DR} than to the gyro sense frequency $f_0-\Omega$. Otherwise, the reference frequency f_R may be selected to be larger than the characteristic frequency f_0, and therefore, closer to the gyro disturbance frequency f_0+f_{DR} than to the gyro sense frequency $f_0+\Omega$.

Nevertheless, the reference frequency f_R needs to be sufficiently far from the peak frequency f_1 of the gyroscope **202** to avoid undesirable amplification that is associated with the intrinsic vibrational mode of the gyroscope at this peak frequency. On the other hand, this reference frequency f_R is not so far from one of the gyro disturbance frequencies that a response from the disturbance signal could be compromised.

FIG. **5**C illustrates an exemplary spectrum diagram **560** that indicates a mechanism to separate one of the two gyro disturbance signals from the two gyro sense signals according to various embodiments in the invention. The two gyro disturbance signals and the two gyro sense signals are converted with respect to the reference signal f_R, and change to different frequencies from their original frequencies in the electronic mixer **306**. As a result, the modulated frequencies of the two gyro disturbance signals are $|f_R-(f_0-f_{RD})|$ and $|f_R-(f_0+f_{RD})|$, respectively, while the modulated frequencies of the two gyro sense signals are $|f_R-(f_0-\Omega)|$ and $|f_R-(f_0+\Omega)|$, respectively. The absolute values are applied, because in some embodiments, the reference frequency f_R is smaller than either of the gyro disturbance frequencies $f_0\pm f_{RD}$ or either of the gyro sense frequencies $f_0\pm\Omega$.

In this embodiment, the reference frequency f_R is larger than the gyro disturbance frequencies $f_0\pm f_{RD}$ and the gyro sense frequencies $f_0\pm\Omega$. The modulated frequencies of the gyro disturbance signal and the two gyro sense signals may be simply represented as $f_R-(f_0-f_{RD})$ and $f_R-(f_0+f_{RD})$, $f_R-(f_0-\Omega)$ and $f_R-(f_0+\Omega)$, respectively.

The cut-off frequency f_{LP} of the low-pass filter **308** is controlled between a smaller frequency of the modulated gyro disturbance frequencies i.e., $|f_R-(f_0-f_{RD})|$ and $|f_R-(f_0+f_{RD})|$, and a smaller frequency of the modulated gyro sense frequencies, i.e., $|f_R-(f_0-\Omega)|$ and $|f_R-(f_0+\Omega)|$. The level of one gyro disturbance signal is retained or amplified by the gain G_{LP}, and on the opposite, the other gyro disturbance signal and the two gyro sense signals are depressed. Upon such modulation based on mixing and low pass filtering, one gyro disturbance signal in the gyro output signal is isolated out, and the peak detector **304** may further determine whether this isolated gyro disturbance signal exceeds the threshold level V_{TH}.

One of those skilled in the art knows that the gyro sensing circuit **300** is preferably applied when the gyro disturbance signals are relatively distant from the gyro sense signals on the frequency spectrum. The difference between the disturbance frequency f_{RD} and the rotation frequency Ω needs to be sufficiently large, such that the cut-off frequency f_{LP} may be controlled to a magnitude in between of them. Therefore, the modulation method based on one demodulation unit **302** is not applicable when the disturbance frequency f_{RD} is substantially close to the sense frequency Ω in FIG. **5**C. Substantial closeness of the shock frequency with another frequency is determined based on whether the cut-off frequency f_{LP} of the low-pass filter **308** may be engineered to differentiate the corresponding modulated frequencies. To be specific, in one embodiment associated with FIG. **5**C, a challenge occurs for the gyro sensing circuit **300** that is based on a single modulation unit **302**, when the modulated gyro disturbance frequency $f_R-f_0-f_{RD}$ and the modulated gyro sense frequency $f_R-f_0-\Omega$ is so close that the low-pass filter **308** may not be easily engineered to differentiate them.

In certain embodiments, the shock signal may also coexist with the gyro disturbance signals, and a similar modulation method may be applied to isolate the shock signal only or isolate both the shock signal and one of the gyro disturbance signals.

However, the modulation method based on one demodulation unit **302** is also not applicable, when the shock frequency f_{SK} is substantially close to one of the gyro disturbance frequencies $f_0\pm f_{RD}$ in FIG. **5**C, and when the shock signal has to be differentiated from the gyro disturbance signals. The gyro sensing circuit **300** that is based on one demodulation unit **302** may fail to output a correct shock flag under this circumstance. Although the gyro disturbance signals are acceptable by the rotation sensing system **200** and the host, the gyro disturbance frequency f_0+f_{RD} may be so close to the shock frequency f_{SK} that the gyro sensing circuit **300** regards the gyro disturbance signals as the shock signal and issues an erroneous shock flag.

In various embodiments associated with FIGS. **4**A-**4**C and **5**A-**5**C, the reference signal may be selected at a single reference frequency f_R, and however, each of the other signals related to the gyro sense signals, the gyro disturbance signals and the shock signal may be associated with a respective frequency bandwidth. Regardless of their bandwidths, the gyro sense signals and the shock signal are simply represented around their respective central frequencies. In these figures, heights of corresponding arrowed lines are not presented in a proportional format to the actual magnitudes of these signals.

FIG. **6** illustrates an exemplary block diagram **600** of a gyro sensing circuit based on a differential demodulation scheme according to various embodiments in the invention. The gyro sensing circuit **600** includes two demodulation units **602**A and **602**B that respectively demodulate the gyro output signals at two reference signals f_{R1} and f_{R2}, compensate the magnitudes of the gyro output signals as needed and band-limit the gyro output signals. In particular, the two reference signals are symmetric with respect to the characteristic frequency f_0, and may thus be represented as $f_0-\Delta f_R$

and $f_0+\Delta f_R$, respectively. The demodulated gyro output signals are further combined differentially by a subtractor **604**. A peak detector **606** further detects whether the magnitude of the combined output signal exceeds a threshold level V_{TH}, and generates a corresponding shock flag to alert the host whether an anomalous shock or disturbance situation occurs.

Such a differential demodulation method is applied to address the above challenges in the non-differential demodulation scheme, when the shock frequency f_{SK} of the shock signal is close to any frequency of the gyro sense signals or the gyro disturbance signals. This method takes advantages of the symmetric nature of both the gyro sense signals and the gyro disturbance signals. These symmetric signals, once demodulated by symmetric reference signals, may substantially cancel off each other via differential combination in the subtractor **604**. As a result, the shock signal may be detected with an enhanced immunity to vibrational sense or disturbance signals coupled in the gyro output signal.

FIG. **7**A illustrates a third exemplary spectrum diagram **720** of inputs coupled into a rotation sensing system according to various embodiments in the invention. In addition to interested rotation of the gyroscope **202**, both a rotational disturbance and a shock may be incorporated into the gyro output signal. In various embodiments, the disturbance frequency f_{RD} of the rotational disturbance may be located within an intermediate frequency range, e.g., 1-5 kHz, while the shock frequency f_{SK} of the shock may have a higher frequency. The characteristic frequency f_0 of the gyroscope **202** may be located in between of the disturbance frequency f_{RD} and the shock frequency f_{SK}.

FIG. **7**B illustrates an exemplary spectrum diagram **740** of signal components in a gyro output signal and two reference signals used in a gyro sensing circuit according to various embodiments in the invention. The interested rotation of the gyroscope **202** is coupled based on the Coriolis force, and modulated to two gyro sense signals that are symmetric with respect to the characteristic frequency f_0. Similarly, the rotational disturbance to the gyroscope **202** is also modulated to two gyro disturbance signals that are symmetric with respect to the characteristic frequency f_0. These two gyro disturbance signals and the two gyro sense signals constitute the signal components in the gyro output signal provided to the rotation sensing system **200**. In some embodiments, the gyro disturbance signals may be further apart from the characteristic frequency f_0 compared with the gyro sense signals.

In addition to the gyro sense and disturbance signals, the gyro output signal further comprises a shock signal that has a shock frequency f_{SK}. This shock signal is not modulated by the gyroscope **202** and is directly incorporated into the gyro output signal. Therefore, the shock signal is not symmetric with respect to the characteristic frequency f_0.

In view of these signal components, two reference signals are applied to demodulate the gyro output signal in the gyro sensing circuit **600**. The first reference signal used by the first demodulation unit **602**A has a first reference frequency f_{R1} that is larger than the characteristic frequency f_0 by Δf_R, and the second reference signal used by the second demodulation unit **602**B has a second reference frequency f_{R2} that is smaller than the characteristic frequency f_0 by Δf_R. As a result, the reference signals, the gyro sense signals and the gyro disturbance signals are symmetric with respect to the characteristic frequency f_0 except the shock signal.

The first reference frequency f_{R1} of the first reference signal is selected to be closer to the shock signal and the gyro disturbance frequency f_0+f_{DR} than to the gyro sense frequency $f_0+\Omega$, and the second reference frequency f_{R2} is therefore closer to the gyro disturbance frequency f_0-f_{DR} than to the gyro sense frequencies $f_0.\Omega$. The reference frequencies f_{R1} and f_{R2} need to be sufficiently far from the peak frequency f_1 of the gyroscope **202** due to the undesirable intrinsic vibrational mode at this peak frequency, while not being so far that responses from the shock signal and the gyro disturbance signals are compromised.

FIG. **7**C illustrates an exemplary spectrum diagram **760** that indicates a differential demodulation mechanism to separate the shock signal from the gyro sense and disturbance signals according to various embodiments in the invention. Due to their symmetry with respect to the characteristic frequency f_0, the two gyro sense signals are demodulated to two sense signals at identical frequencies $\Delta f_R \pm \Omega$ by both the first and second demodulation units **602**A and **602**B, except that the positions of the two demodulated sense signals are opposite in the frequency spectrum **760** of the two corresponding demodulations. Likewise, the two gyro disturbance signals are demodulated to two disturbance signals at identical frequencies $\Delta f_R \pm |f_{RD}-f_p|$, and the positions of the two demodulated gyro disturbance signals are also opposite in the frequency spectrum **760** of the two corresponding demodulations. In contrast with the gyro sense and disturbance signals, the shock signal is asymmetric with respect to the characteristic frequency f_0, and the demodulated shock signals respectively centers at two distinct frequencies $|f_0+\Delta f_R-f_{SK}|$ and $|f_0+\Delta f_R-f_{SK}|$ in the frequency spectrum **760** associated with the two corresponding demodulations.

Although the respective two frequencies of either the demodulated sense or disturbance signals match, their amplitudes are not necessarily so, because the gyroscope **202** that has the characteristic frequency f_0 and the peak frequency f_1 may have distinct filtering effects on the signals that are symmetric with respect to the characteristic frequency f_0. In accordance with some embodiments, the demodulated gyro output signals are compensated within the first and second demodulation units **602**A and **602**B in order to neutralize the filtering effects of the gyroscope **202**. In one embodiment, such compensation is mainly obtained by tailoring the gains G_{LP1} and G_{LP2} for filtering in the first and second demodulation units **602**A and **602**B. In another embodiment, the phases Φ_{R1} and Φ_{R2} of the first and second reference signals are also adjusted to compensate filtering effects of the gyroscope **202**. Based on such compensation, the amplitudes of the demodulated disturbance signals matches with each other and may be cancelled off by subtraction, and in some embodiments, so do the amplitudes of the demodulated sense signals.

The cut-off frequencies f_{LP1} and f_{LP2} are equal for filtering in the first and second demodulation units **602**A and **602**B. Due to differential combination in the subtractor **604**, the cut-off frequencies f_{LP1} and f_{LP2} are relatively easier to control. In certain embodiments, both the demodulated disturbance signals and the demodulated sense signals are matched, so the cut-off frequencies f_{LP1} and f_{LP2} just need to be controlled between the distinct frequencies $|f_0+\Delta f_R-f_{SK}|$ and $|f_0+\Delta f_R-f_{SK}|$ of the two modulated shock signals. When the second demodulated gyro output signal is subtracted from the first demodulated gyro output signal, the modulated gyro disturbance signals and the modulated gyro sense signals automatically cancel off each other.

In one embodiment, the amplitudes of the demodulated disturbance signals are matched, while those of the demodulated sense signals are not. The cut-off frequencies f_{LP1} and f_{LP2} need to be better controlled below the frequencies of the

demodulated sense signals, such that the uncompensated sense signals may be suppressed by filtering. Nevertheless, it is easier to control the cut-off frequencies f_{LP1} and f_{LP2} in such a manner than to control them between the shock signal and the demodulated disturbance signals.

Based on two differential demodulations, one shock signal in the gyro output signal is isolated, and the peak detector **304** may further determine whether this isolated shock signal exceeds the threshold level V_{TH}. One of those skilled in the art knows that the gyro sensing circuit **600** is effective to address the issues when the frequency of the shock signal is close to that of one gyro disturbance signal and/or that of one gyro sense signal.

In various embodiments associated with FIGS. **7**A-**7**C, the reference signals may be selected at the two specific reference frequencies f_{R1} and f_{R2}, and however, each of the other signals concerning the gyro sense signals and the shock signal may be associated with a respective frequency bandwidth. Regardless of their bandwidths, the gyro sense signals and the shock signal are simply represented around their respective central frequency. Like FIGS. **4**A-**4**C and **5**A-**5**C, heights of corresponding arrowed lines in FIGS. **7**A-**7**C are not presented in a proportional format to the actual magnitudes of these signals.

FIG. **8** illustrates another exemplary block diagram **800** of a gyro sensing circuit based on a differential demodulation scheme according to various embodiments in the invention. As an embodiment of the gyro sensing circuit **600**, either of the demodulation units **602**A or **602**B comprises an electronic mixer and a low pass filter that are coupled to each other. The electronic mixers **802**A and **802**B in the demodulation units **602**A or **602**B mix the gyro output signal with two reference signals that adopt two distinct reference frequencies ($f_0+\Delta f_R$ and $f_0-\Delta f_R$) and two distinct phases (Φ_{R1} and Φ_{R2}), respectively. The corresponding low-pass filters **804**A and **804**B further filter the respective mixed gyro output signals based on two distinct gains G_{LP1} and G_{LP2} but two consistent cut-off frequency f_{LP1} and f_{LP2}. The two consistent cut-off frequency f_{LP1} and f_{LP2} is equal to one single frequency f_{LP}. In various embodiments of the invention, the phases Φ_{R1} and Φ_{R2} of the reference signals and/or the gains G_{LP1} and G_{LP2} of the filters are tailored to compensate the potentially distinct filtering effects that the gyroscope **202** have on the gyro sense and disturbance signals having frequencies higher or lower than the characteristic frequency f_0.

The two demodulated gyro output signals are differentially combined within the subtractor **604**, such that the second demodulated gyro output signal is subtracted from the first demodulated gyro output signal to generate a combined gyro output signal. Due to compensation, the two demodulated gyro disturbance signals cancel off each other in the two demodulated gyro output signals, and in some embodiments, so do the two demodulated gyro sense signals. The demodulated shock signal is included in the combined gyro output signal and effectively isolated from the gyro sense or disturbance signals.

The following peak detector **606** comprises a sampling circuit **806** and a comparator **808**. The sampling circuit **806** samples the combined gyro output signal received from the subtractor **604**. The comparator **808** compares the sampled signal with the threshold level V_{TH} and generates the shock flag according to a comparison result.

FIG. **9**A illustrates an exemplary flow diagram **900** of a method for flagging a disturbance or a shock experienced by a rotation sensing system according to various embodiments in the invention. FIG. **9**B illustrates another exemplary flow diagram **950** of a method for flagging a shock experienced by a rotation sensing system according to various embodiments in the invention. The methods **900** and **950** are based on a non-differential demodulation scheme and a differential demodulation scheme, respectively.

The method **900** of flagging the shock or disturbance initializes with receiving a gyro output signal from a gyroscope at step **902**. Besides gyro sense signals related to an interested rate of rotation, the gyro output signal further includes the shock signal or the gyro disturbance signals.

In order to separate a shock signal or a gyro disturbance signal, such a gyro output signal is demodulated using a reference signal that has a reference frequency f_R at step **904**. During demodulation, the gyro output signal is mixed with the reference signal, and further band limited according to a cut-off frequency f_{LP}. The shock signal or the gyro disturbance signals included in the gyro output signal is therefore demodulated together with the interested gyro sense signals. In one embodiment, the shock signal exists while no gyro disturbance signals are involved, so the cut-off frequency f_{LP} is set between the frequencies of the demodulated shock signal and the demodulated gyro sense signals. In another embodiment, the gyro disturbance signals are involved in the gyro output signal while no shock signal is incorporated, so the cut-off frequency f_{LP} is set between the respective lower frequencies of the demodulated gyro sense and disturbance signals. In certain embodiments, both the gyro disturbance signals and the shock signal are included in the gyro output signal in addition to the gyro sense signals, and the cut-off frequency f_{LP} is set between the frequency of the demodulated shock signal and the lower frequency of the demodulated gyro disturbance signals or between the respective lower frequencies of the demodulated gyro sense and disturbance signals. As a result, the demodulated shock signal or one demodulated gyro disturbance signal is retained, while the other signal components are depressed in the demodulated gyro output signal.

At step **906**, it is determined whether the demodulated gyro output signal exceeds a threshold value V_{TH}A shock flag is issued to a host of the rotation sensing circuit to acknowledge existence of the shock or disturbance and corruption of the gyro sense signals related to the interested rotation information.

The method **950** of flagging the shock or disturbance also initializes with receiving a gyro output signal from a gyroscope at step **952**. Besides gyro sense signals related to an interested rate of rotation, the gyro output signal includes a shock signal, and may further incorporate gyro disturbance signals as well. The gyro sense and disturbance signals are symmetric with respect to the characteristic frequency f_0 of the gyroscope, while the shock signal is not so.

At step **954**, such a gyro output signal is demodulated using a first reference signal that has a first reference frequency f_{R1}. At step **956**, the gyro output signal is also demodulated using a second reference signal that has a second reference frequency f_{R2}. During either demodulation, the gyro output signal is mixed with the first or second reference signal and further band limited according to a cut-off frequency f_{LP1} or f_{LP2}. The first and second reference signals are selected to be symmetric with respect to the characteristic frequency f_0. The phases of the first and second reference signals and/or the gains of band limiting are adjusted to compensate distinct filtering impacts the gyroscope has on distinct gyro sense signals or distinct gyro disturbance signals. The demodulated gyro sense signals

have consistent magnitudes upon such compensation, and so do the demodulated gyro disturbance signals if they are originally incorporated.

At step **958**, the first demodulated gyro output signal from step **954** is differentially combined with the second demodulated gyro output signal from step **956**. In some embodiments, the gyro sense signals that are symmetric to the characteristic frequency f_0 are substantially cancelled off, and so are the gyro disturbance signals if they are incorporated in the gyro output signal. As a result, the combined gyro output signal includes the demodulated shock signal that is therefore isolated from the gyro sense and/or disturbance signals.

At step **960**, it is determined whether the combined gyro output signal exceeds a threshold value V_{TH}. A shock flag is issued to a host of the rotation sensing circuit to acknowledge existence of the shock or disturbance and corruption of the gyro sense signals related to the interested rotation information.

The method **900** that is based on non-differential demodulation involves a single demodulation step, but is difficult to apply when a shock signal is close to a gyro sense signal or a gyro disturbance signal. In contrast, the method **950** involves two complementary demodulation steps and may be applied in the above challenging situation that the method **900** has difficulty to handle.

While the invention is susceptible to various modifications and alternative forms, specific examples thereof have been shown in the drawings and are herein described in detail. It should be understood, however, that the invention is not to be limited to the particular forms disclosed, but to the contrary, the invention is to cover all modifications, equivalents, and alternatives falling within the scope of the appended claims.

We claim:

1. A gyroscope sensing circuit comprising:

a first demodulation unit coupled to receive a first signal from a gyroscope, the first demodulation unit demodulates the first signal to a first demodulated signal using a first reference signal;

a second demodulation unit coupled to receive the first signal from the gyroscope, the second demodulation unit demodulates the first signal to a second demodulated signal output using a second reference signal;

a subtractor coupled to the first and second demodulation units, the subtractor isolates a shock signal that is asymmetric with respect to a characteristic frequency of the gyroscope; and

a detector coupled to the subtractor, the detector determines whether the shock signal exceeds a threshold level.

2. The gyroscope sensing circuit of claim **1** wherein the first signal comprises a shock signal and a plurality of gyroscope sense signals that are related to a rate of rotation.

3. The gyroscope sensing circuit of claim **2** wherein the plurality of gyroscope sense signals is symmetric with respect to the characteristic frequency of the gyroscope.

4. The gyroscope sensing circuit of claim **3** wherein the subtractor suppresses the symmetric gyroscope sense signals using a differential combination process.

5. The gyroscope sensing circuit of claim **1** wherein the first and second reference signals are symmetric with respect to a characteristic frequency of the gyroscope.

6. The gyroscope sensing circuit of claim **1** wherein the detector generates an alert in response to the shock signal exceeding the threshold level.

7. A gyroscope sensing circuit comprising:

a first demodulation unit coupled to receive a first signal from a gyroscope including at least one gyroscope sense signal, a shock signal and at least one gyroscope disturbance signals, the first demodulation unit demodulates the first signal to a first demodulated signal using a first reference signal;

a filter coupled within the first demodulation unit, the filter retains the shock signal and the at least one disturbance signal according to a defined frequency bandwidth, the at least one gyroscope sense signal being outside of the defined frequency bandwidth, the filter generating a filtered first demodulated signal; and

a detector coupled to receive the filtered demodulated signal, the detector determines whether the filtered demodulated signal exceeds a threshold level.

8. The gyroscope sensing circuit of claim **7** wherein the at least one gyroscope disturbance signal is symmetric with respect to a characteristic frequency of the gyroscope.

9. The gyroscope sensing circuit of claim **8** wherein the first reference signal is associate with a first phase having distinct filtering effects related to gyroscope signals that are symmetric with respect to the characteristic frequency.

10. The gyroscope sensing circuit of claim **8** wherein a first frequency of the first reference signal is selected to be closer to a second frequency of the shock signal in relation to a third frequency of the at least one gyroscope sense signal.

11. The gyroscope sensing circuit of claim **7**, wherein the first demodulation unit further comprises:

a first mixer that combines the first reference signal and the first signal; and

a first low-pass filter, coupled to the first mixer, the first low-pass filter adopts a first filter gain and a first cut-off frequency that relate the defined frequency bandwidth.

12. The gyroscope sensing circuit of claim **11** wherein the first mixer varies a spectrum content of the first signal with respect to a first reference frequency of the first reference signal.

13. A method for identifying a shock to a gyroscope, the method comprising the steps of:

receiving a first signal from the gyroscope, the first signal including a shock signal and a plurality of sense signals;

demodulating the first signal and generating a first demodulated signal using a first reference signal;

demodulating the first signal and generating a second demodulated signal using a second reference signal;

combining the first and second demodulated signals to isolate the shock signal; and

determining whether the combined demodulated signals exceeds a threshold level.

14. The method of claim **13** wherein the first and second reference signals are symmetric with respect to a characteristic frequency of the gyroscope.

15. The method of claim **13** wherein the shock signal is asymmetric with respect to a characteristic frequency of the gyroscope.

16. The method of claim **13** wherein the step of combining the first and second demodulated signals suppresses the plurality of sense signals using a differential combination process.

17. The method of claim **13** further comprising the step of generating an alert in response to the shock signal exceeding the threshold level.

18. The method of claim 13 further comprising the steps of:

combining the first reference signal with the first signal using a first mixer and generating a first mixed signal;

applying the first mixed signal to a first filter;

combining the second reference signal with the first signal using a second mixer and generating a second mixed signal; and

applying the second mixed signal to a second filter.

19. The method of claim 13 further comprising the step of sampling the combined first and second demodulated signals prior to determining whether the combined demodulated signals exceed the threshold level.

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